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I, JANENE PEISKER, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2004901679 for a patent by AUSTRALIAN MAGNESIUM OPERATIONS PTY LTD as filed on 30 March 2004.

I further certify that the name of the applicant has been amended to ADVANCED MAGNESIUM TECHNOLOGIES PTY LTD pursuant to the provisions of Section 104 of the Patents Act 1990.



WITNESS my hand this  
Eighth day of April 2005

A handwritten signature in dark ink, appearing to read 'J. Peisker'.

JANENE PEISKER  
TEAM LEADER EXAMINATION  
SUPPORT AND SALES

AUSTRALIA  
Patents Act 1990

PROVISIONAL SPECIFICATION

Applicant:

AUSTRALIAN MAGNESIUM OPERATIONS PTY LTD

Invention Title:

MELTING APPARATUS AND METHOD

The invention is described in the following statement:

#### FIELD OF THE INVENTION

The present invention relates to methods and apparatus for melting pieces of solid metal in a bath of molten metal. The present invention has particular application, though not exclusive application, in relation to magnesium and magnesium alloys.

#### BACKGROUND TO THE INVENTION

The ease with which molten magnesium oxidises generally results in significant losses of metal during molten metal processing. This is particularly so in those high pressure die casting plants that tend to have a large amount of internally recycled metal. Melt losses, and their consequences, add considerably to the cost of diecastings because:

- up to 10% of purchased metal is lost to dross and sludge in some operations with the industry average for high pressure die casting being approximately 5%;
- the effect of melt loss is exacerbated each time metal is melted during recycling;
- dross and sludge cannot be readily recycled and therefore removal, transport, treatment and disposal of residues attract significant costs;
- of the increased risk of inclusions in the cast part with attendant higher scrap rates;
- of downtime of the melting furnace and the diecasting machine, and associated labour, to clean out accumulated sludge;
- of reduced furnace capacities due to accumulation of sludge; and
- due to its insulating effect, the presence of sludge reduces heat transfer from the heating medium to the

molten magnesium, which results in poorer temperature control, extension of heating cycles and decreased crucible life due to increased temperatures at the crucible wall.

5           Dross is produced through reaction with air and moisture at the surface of the melt. The production of dross can be reduced by ensuring good seals at crucible lids, selection of an effective cover gas, good cover gas distribution to the melt surface, minimisation of melt  
10 surface area and reduction of disturbances to the melt surface.

          Sludge mainly contains Fe-Mn-Al intermetallic compounds, oxides that have sunk rather than floated, and entrapped magnesium alloy. Intermetallics form because Fe  
15 dissolves from the crucible walls and reacts with Mn and Al in the melt. In this way Fe levels are kept low, but it is important to minimise this reaction otherwise sludge volumes and crucible maintenance increase and further additions of Mn may be necessary.

20           Intermetallics will also form if the temperature of the liquid falls below the equilibrium level set by the concentrations of Fe and Mn in solution in the liquid pool. This level will initially be set by the composition of the incoming metal, but will change with time in the  
25 crucible. Intermittent operation of a melting furnace will also lead to the formation of aluminium-rich compounds in the sludge. This in turn leads to increased dissolution of iron from the crucible.

          The rate of dissolution of Fe increases with  
30 increasing temperature and the driving force for precipitation of intermetallics increases with decreasing temperature. Thus, if there are significant temperature differences in a melting furnace then large amounts of Fe

will dissolve at hot spots on the crucible walls and this will result in the precipitation of intermetallics in cooler areas. Because melting involves the introduction of cold material to a melt, the situation in a melting furnace inherently involves hot and cold spots and so has the potential to generate large amounts of sludge.

An arrangement for melting which minimises the formation of dross and sludge would be of significant benefit to the magnesium industry, and particularly the magnesium die casting industry, because it would increase the efficiencies of melting operations and facilitate more efficient recycling of scrap.

#### SUMMARY OF THE INVENTION

In a first aspect, the present invention provides a method of melting pieces of solid metal in a bath of molten metal, the method comprising the steps of:

introducing the solid metal into a melting apparatus which is in fluid communication with the molten metal bath whilst maintaining the upper surface of the bath externally of the melting apparatus substantially quiescent; and

inducing flow of molten metal through the melting apparatus and over solid metal contained therein whilst maintaining the upper surface of the bath, both internally and externally of the melting apparatus, substantially quiescent.

Preferably, the pieces of solid metal are introduced into the melting apparatus with a view to minimal disturbance of the upper surface of the molten metal bath within the melting apparatus.

The flow of molten metal through the melting apparatus and over solid metal contained in the melting

apparatus not only facilitates more rapid melting of the solid metal but also results in circulation of molten metal through the bath which reduces temperature variations within the bath. Preferably, the temperature  
5 variation within the bulk of the bath is less than  $\pm 5^{\circ}\text{C}$ , more preferably less than  $\pm 2^{\circ}\text{C}$ , most preferably less than  $\pm 1^{\circ}\text{C}$ .

The flow of molten metal may be induced in a variety of ways including a pump or impellor located  
10 remotely from the melting apparatus. Preferably however, the flow of molten metal is induced by an impellor mounted within the melting apparatus.

The molten metal may be induced to flow through the melting apparatus in any direction but preferably, the  
15 flow is substantially vertically through the melting apparatus. The molten metal may be induced to flow downwardly through the melting apparatus but preferably the molten metal is induced to flow upwardly through the melting apparatus. The rate of flow may be varied during  
20 the melting process and the direction of flow may be reversed during the melting process.

In a second aspect, the present invention provides a melting apparatus for melting pieces of solid metal in a bath of molten metal, the melting apparatus  
25 comprising:

a device having a lower portion, an upper portion, and a body portion extending therebetween which is formed with a plurality of apertures therein, the device arranged, in use, with the lower portion and the  
30 plurality of apertures in the body portion positioned within the bath of molten metal and the upper portion positioned above the upper surface of the molten metal

bath;

introduction means for introducing the solid metal into the device through the upper portion of the device;

5 flow inducing means for inducing movement of molten metal through the device; and

flow straightening means for encouraging axial flow of molten metal through the device.

The flow inducing means may induce movement of  
10 molten metal in any direction through the device but preferably, the molten metal is induced to move substantially vertically through the device. The molten metal may be induced to flow upwardly through the device with the molten metal entering the device through the  
15 lower portion and exiting the device through the apertures. Alternatively, the molten metal may be induced to flow downwardly through the device with the molten metal entering the device through the apertures and exiting the device through the lower portion.

20 The flow inducing means may take the form of an impellor mounted within the device in which case the flow straightening means preferably takes the form of baffles in a grid arrangement which encourages axial flow of the molten metal by minimising the radial component of the  
25 flow induced by the impellor and thereby minimises the tendency for a vortex to form at the surface of the molten metal within the device. The height of the baffles in the direction of flow is preferably much greater than the width of each baffle forming the grid. Preferably one  
30 baffle grid is located above the impellor and another baffle grid below the impellor.

Preferably, the plurality of apertures are formed in a band which extends substantially around the body

portion.

The melting apparatus may be of any shape but the body portion is preferably circular in cross-section.

Preferably, the melting apparatus further  
5 comprises flow diversion means for directing molten metal exiting the body through the apertures away from the upper surface of the molten metal bath. The flow diversion means may take the form of a collar or skirt which projects from the body from a level above the apertures.  
10 Preferably, the collar/skirt surrounds the melting apparatus and projects outwardly and downwardly from the body.

At least preferred embodiments of the present invention enable:

- 15 • rapid melting of solid metal in the flow of molten metal within the melting apparatus;
- efficient circulation of molten metal which minimises temperature fluctuations in the bath as a whole;
- maintenance of a quiescent melt surface outside the  
20 melting apparatus;
- minimal disturbance of the melt surface within the melting apparatus when new solid metal is introduced;
- suspension of particulate impurities entering the melt so that they do not accumulate in the bath and hence can  
25 be removed in a subsequent settling furnace;
- improved heat transfer between the crucible wall and the molten metal;
- prevention of the accumulation of cold liquid around the melting solid; and  
30 • prevention of the accumulation of cold liquid at any other point in the bath.

Use of the present invention in combination with

good seals and cover gas technology can result in very low rates of dross and sludge production and at least preferred embodiments of the present invention facilitate an approximate doubling of the rate at which metal can be melted in a conventional melting furnace.

The present invention may be used in a recycling or refining operation where a salt flux is used to assist in separation of non-metallics from the molten metal.

10 BRIEF DESCRIPTION OF DRAWINGS

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a side elevation of a melting apparatus according to the present invention;

Figure 2 is a side elevation of an alternative embodiment of the melting apparatus of Figure 1;

Figure 3 is a side elevation of an alternative embodiment of the melting apparatus of Figure 1, tailored to suit a feed of small scale pieces such as shredded material or chips;

Figure 4 is a side elevation of the melting apparatus of Figure 3 with the addition of flow enhancing directional skirts; and

Figure 5 is a side elevation of the melting apparatus of Figure 3 in a configuration where the extent of free liquid metal surface is minimised.

DRAWING RELATED DESCRIPTION

Referring initially to Figure 1, a bath of liquid metal 10 having an upper surface 12 is contained by a crucible (not shown) in a furnace (not shown). A gas space 14 is formed between a furnace lid 16 and the liquid

metal level 12. In the case where a reactive metal such as magnesium is being contained the gas space 14 will be occupied by a protective cover gas atmosphere; the composition of which will be known to practitioners of the art. In situations where a flux is being used for a recycling or refining operation the surface of the molten metal will be covered by a layer of flux. In this situation a protective cover gas atmosphere may or may not be contained in the gas space 14. In the case of more inert metals being contained no special atmosphere will be required.

The melting apparatus generally comprises a device 18 having an upper portion 20, a lower portion 22, and a body portion 24 which extends between the upper portion 20 and lower portion 22. The upper portion 20 is formed with introduction means in the form of a lid 26 for introducing solid metal into the device 18. Flow of molten metal upwardly through the device 18 is induced by rotation of impellor 28 which is mounted on drive shaft 30 which is driven by variable speed motor 32. Motor 32 may be of any form but will typically be electrically or pneumatically driven. Molten metal is drawn into the device 18 through entry port 34 in lower portion 22, flows upwardly through the device 18, and exits through apertures 36 in body portion 24. The apertures 36 may be of any shape and may take the form of slots. A different form of apertures 36 is illustrated in Figure 2.

The melting apparatus has two flow straightening baffles in the form of grids 38; one above the impellor 28 and one below the impellor 28. The baffle grids 38 encourage axial flow of the molten metal by minimising the radial component of the flow and thereby minimise the tendency for a vortex to form at the surface 12 of the

molten metal within the device 18. The baffle grids 38 also increase the effectiveness of the pumping action of the impellor 28.

5 The apertures 36 are positioned below the liquid surface 12 to ensure the liquid returning to the bath 10 does so with minimal disturbance of the liquid surface 12.

When the melting apparatus is operated so as to direct the flow of liquid down through the device 18, the apertures 36 become liquid metal entry points and port 34  
10 becomes the liquid exit point.

Solid material is introduced into the upper portion 20 of the apparatus through lid 26. The method of introduction of the solid is dependent on the form and shape of the solid pieces. Large scale solid pieces are  
15 desirably introduced into the liquid in a controlled fashion to minimise splashing. A robotic arm or similar mechanical device specifically designed to feed the solid pieces into the device 18 in a controlled fashion may be utilised.

20 On entering the liquid metal the circulation of the liquid over the solid promotes the rapid melting of the solid. In the case of lighter pieces of solid the melting will typically take place below the liquid surface 12 in the general area of the region marked A. The flow  
25 of liquid over the solid pieces provides a zone of accelerated melting. In the case of larger pieces such as ingots melting will typically take place in the region of reduced cross-sectional area marked B. The reduced cross-section provides a zone of higher velocity liquid metal  
30 around the solid metal which improves the heat transfer rate from the liquid to the solid thus reducing the time taken to melt the solid. For larger pieces the apparatus may include a screen 39 (see Figure 2) for supporting the

pieces during melting.

A protective tube 40 surrounds the impellor drive shaft 30. The tube 40 helps prevent the formation of a vortex around the rotating shaft 30 that might otherwise lead to the entrapment of metallic oxides within the bath. The tube 40 also acts to prevent damage to the drive shaft 30 during the introduction of heavier solid pieces into the apparatus. An inert gas, such as argon, or a protective gas may be introduced into the tube 40 through a valve 42 to help prevent a significant build up of oxide at the liquid surface 12 where the drive shaft 30 enters the liquid bath 10 and thus reduce the tendency for clogging or jamming of the rotating shaft.

In the case where only small scale solid pieces are to be handled, the melting apparatus of the present invention can be simplified to that illustrated in Figure 3 in which like reference numerals are utilised to Figure 1. The small scale solid pieces would typically be produced by a shredding or chipping operation.

The solid pieces are fed into the apparatus through an access port 42 after opening a removable cover 44 using any desired type of materials handling equipment. The supply of the solid pieces would be regulated to match the heat input rate of the furnace, the melting rate of the solid pieces and the rate of liquid removal from the furnace. Protective atmosphere, if required, may be introduced via valve 46 into the access port 42 to help maintain the desired protective atmosphere above the liquid metal bath which would otherwise be diluted or disturbed by the opening of the cover 44 and the introduction of the solid pieces.

The simplified design of the embodiment of Figure 3 facilitates removal of the internal structures of the

melting apparatus, such as the drive shaft and the  
impellor, without the need to completely dismantle or  
remove the apparatus from its installed position in the  
furnace. Suitable apertures can be made in the upper  
5 baffle grid 38 to allow withdrawal of the impellor.

Figure 4 is an embodiment equivalent to Figure 3  
but which features a flow diversion device in the form of  
skirt 48 which minimises disturbance of the surface 12 as  
molten metal exits apertures 36. The skirt 48 directs the  
10 flow of liquid down into the liquid bath 10 away from the  
liquid surface 12. It will be appreciated that a skirt 48  
could be equally employed with the embodiments of Figure 1  
or Figure 2.

Figure 5 is also an embodiment equivalent to  
15 Figure 3. In the embodiment of Figure 5 the gas space  
above the molten liquid bath externally of the device 18  
is removed altogether. The removal of the gas space could  
be achieved equally well in the embodiments of Figure 1 or  
Figure 2. In the embodiment of Figure 5, the skirt 48  
20 shown in Figure 4 is effectively extended to connect with  
and join the crucible walls. The furnace 50 and furnace  
cover 52 are arranged to accommodate a crucible with  
closed-in top 54. The liquid contained in the crucible  
completely fills the vessel thereby removing the need for  
25 a gas space above the liquid surface externally of the  
device 18. The movement of liquid and general operation  
of this embodiment of the present invention occurs in the  
manner previously described with the added benefit of  
eliminating the possibility of disturbing the liquid  
30 surface and entraining any oxides or surface contaminants  
into the bulk of the bath.

In the embodiment of Figure 5, apertures 36 are  
positioned close to the point where the crucible lid 54

joins the device 18 to avoid the formation of a gas pocket and the entrainment of the entrapped gas into the bulk of the bath under the action of the apparatus. In use, the liquid level 12 inside the device 18 would be maintained  
5 above the level where the crucible lid 54 joins the device 18 to similarly avoid formation of a gas pocket.

In the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or  
10 variations such as "comprises" or "comprising" is used in an inclusive sense, ie. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

15

Variations and modifications may be made in respect of the invention described above and defined in the following statement of claims:

1. A method of melting pieces of solid metal  
5 in a bath of molten metal, the method comprising the steps of:

introducing the solid metal into a melting apparatus which is in fluid communication with the molten metal bath whilst maintaining the upper surface of the  
10 bath externally of the melting apparatus substantially quiescent; and

inducing flow of molten metal through the melting apparatus and over solid metal contained therein whilst maintaining the upper surface of the bath, both  
15 internally and externally of the melting apparatus, substantially quiescent.

2. A melting apparatus for melting pieces of solid metal in a bath of molten metal, the melting apparatus comprising:

20 a device having a lower portion, an upper portion, and a body portion extending therebetween which is formed with a plurality of apertures therein, the device arranged, in use, with the lower portion and the plurality of apertures in the body portion positioned  
25 within the bath of molten metal and the upper portion positioned above the upper surface of the molten metal bath;

introduction means for introducing the solid metal into the device through the upper portion of the  
30 device;

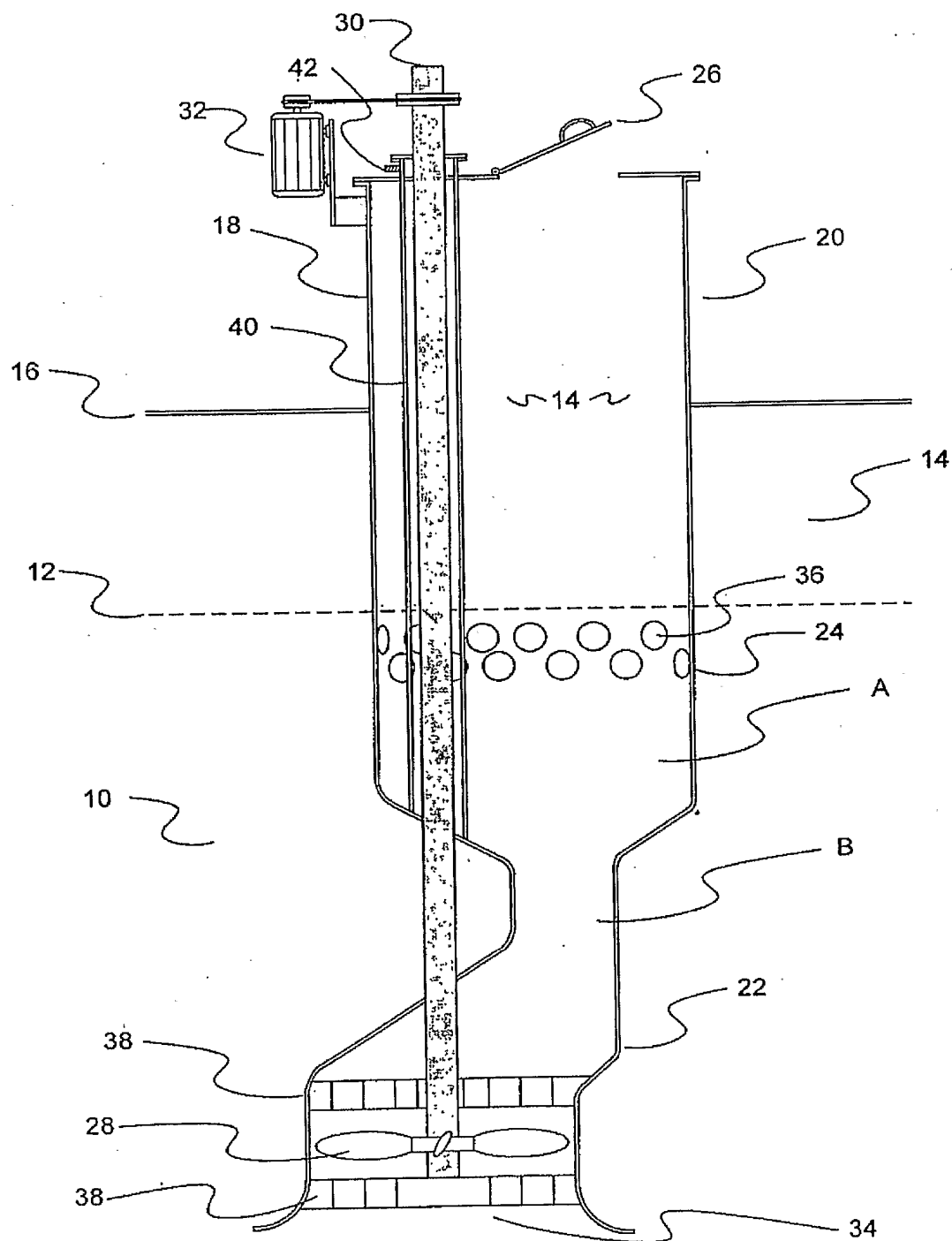
flow inducing means for inducing movement of molten metal through the device; and

flow straightening means for encouraging axial  
flow of molten metal through the device.

5

Dated this 30<sup>th</sup> day of March 2004  
AUSTRALIAN MAGNESIUM OPERATIONS PTY LTD

By its Patent Attorneys  
GRIFFITH HACK





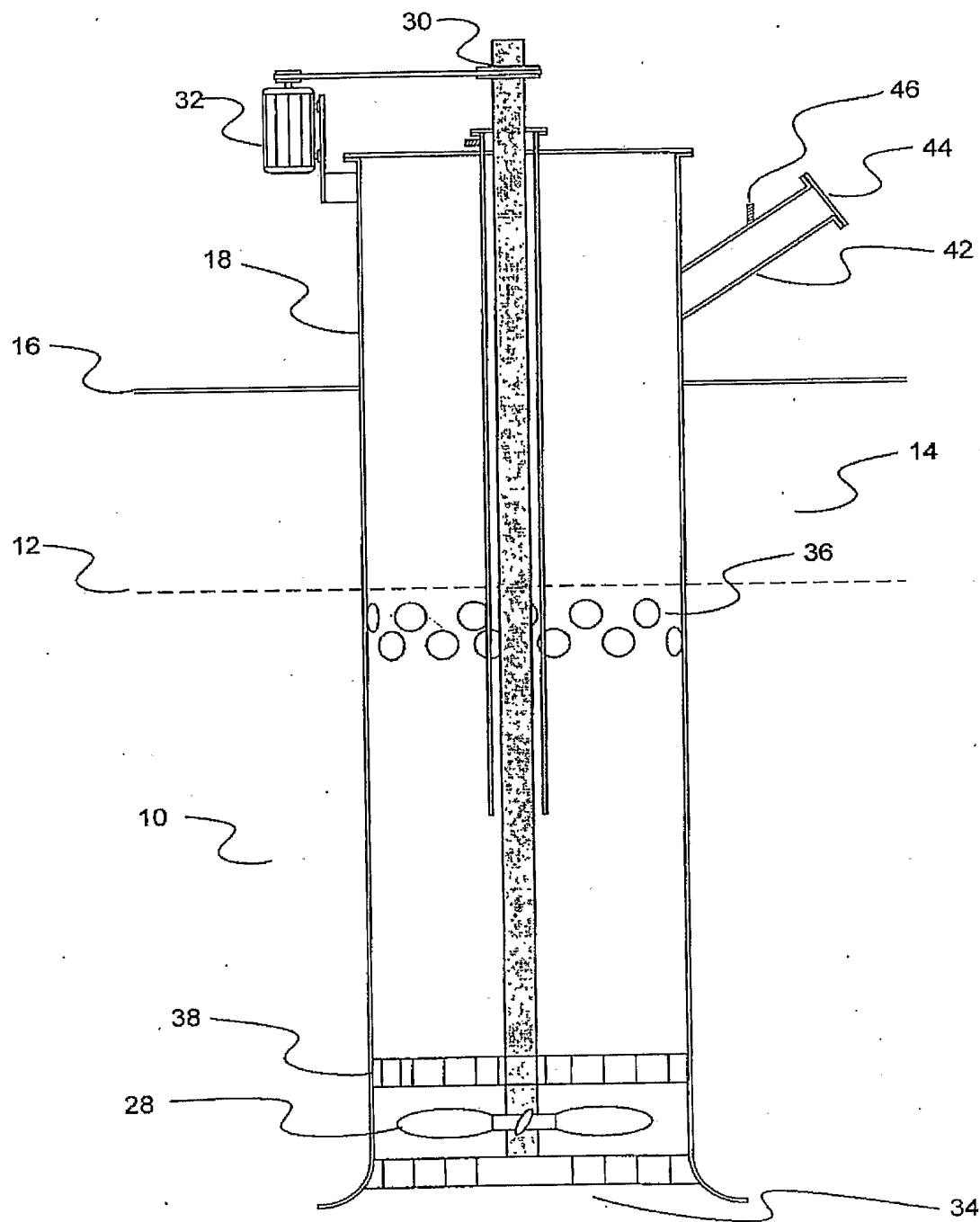


FIG. 3.

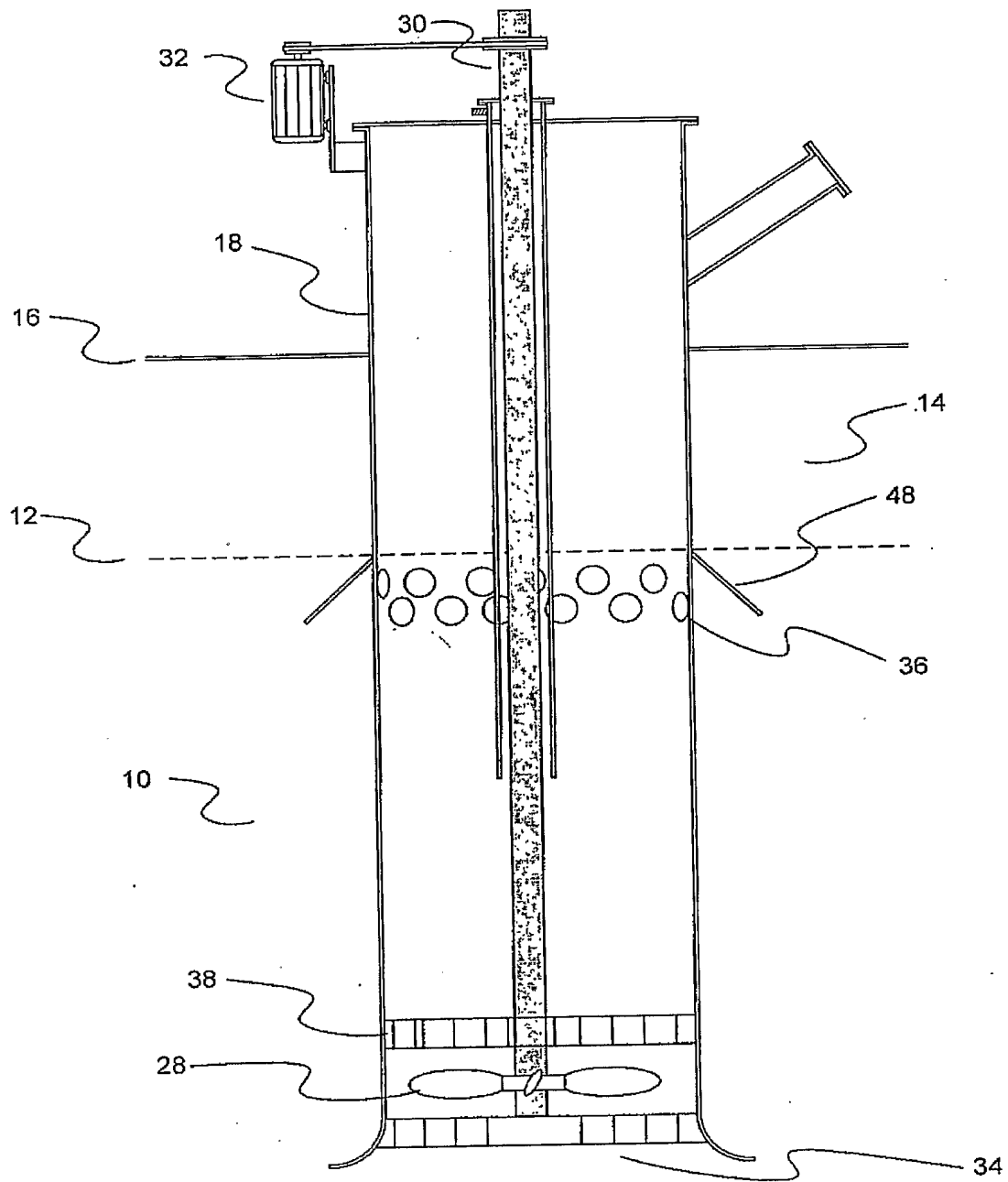


FIG. 4.

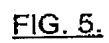


FIG. 5.